Fish diets and food webs in the Northwest Territories: round whitefish (*Prosopium cylindraceum*)

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FISH DIETS AND FOOD WEBS IN THE NORTHWEST TERRITORIES: ROUND WHITEFISH (*Prosopium cylindraceum*)

by

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ABSTRACT

Stewart, D.B., Carmichael, T.J., Sawatzky, C.D., Reist, J.D., and Mochnacz, N.J. 2007. Fish diets and food webs in the Northwest Territories: round whitefish (*Prosopium cylindraceum*). Can. Manuscr. Rep. Fish. Aquat. Sci. 2794: iv + 21 p.

Round whitefish prey opportunistically on small benthic organisms in shallow inshore waters of lakes, rivers, and estuaries. During the open water period, juveniles and adults eat a variety of aquatic insect larvae, pupae and nymphs, benthic molluscs, small crustaceans, fish eggs, and fish. Young-of-the-year eat mostly aquatic insect larvae and pupae. Little is known of seasonal changes in the species' diet or about its winter diet. Piscivorous fishes are likely the key predators on the round whitefish, which is seldom targeted for harvest. Intra- and inter-specific competition for food may limit growth, and the introduction of warm-water predators such as smallmouth bass (*Micropterus dolomieu*), yellow perch (*Perca flavescens*), and rainbow smelt (*Osmerus mordax*) can cause populations to decline. This document provides a generalized food web for the round whitefish, and reviews knowledge of the species' interactions with predators, prey, and competitors. Dietary differences related to geographical location, habitat type, life history stage, season, predation, and competition are discussed.

Key words: diet; life history; habitat use; fresh water; fluvial; adfluvial; lacustrine; anadromous; Coregonidae; feeding behaviour.

RÉSUMÉ

Stewart, D.B., Carmichael, T.J., Sawatzky, C.D., Reist, J.D., and Mochnacz, N.J. 2007. Fish diets and food webs in the Northwest Territories: round whitefish (*Prosopium cylindraceum*). Can. Manuscr. Rep. Fish. Aquat. Sci. 2794: iv + 21 p.

Le ménomini rond s'alimente de façon opportuniste de petits organismes benthiques dans les eaux littorales peu profondes des lacs, des rivières et des estuaires. Durant la saison des eaux libres, les juvéniles et les adultes consomment des larves, des pupes et des nymphes d'insectes aquatiques, des mollusques benthiques, des petits crustacés, des œufs de poisson et du poisson. Les jeunes de l'année mangent principalement des larves et des pupes d'insectes aquatiques. On en connaît peu à propos des changements saisonniers dans le régime alimentaire de l'espèce ou au sujet de son régime alimentaire d'hiver. Les poissons piscivores sont probablement les principaux prédateurs du ménomini rond, qui fait rarement l'objet d'une récolte. La compétition pour la nourriture au sein de l'espèce et entre les espèces peut limiter la croissance de ce poisson et l'introduction de prédateurs des eaux tempérées, tels l'achigan à petite bouche (*Micropterus dolomieu*), la perchaude (*Perca flavescens*) et l'éperlan (*Osmerus mordax*), peut entraîner un déclin des populations. Nous présentons un réseau trophique généralisé pour le ménomini rond et nous évaluons les connaissances sur ses interactions avec ses prédateurs, ses proies et ses compétiteurs. Nous examinons également les différences dans son alimentation reliées aux emplacements géographiques, aux types d'habitat, aux stades du cycle vital, aux saisons, à la prédation et à la compétition.

Mots clés : régime alimentaire; cycle vital; utilisation d'habitat; eau douce; fluvial; adfluvial; lacustre; anadrome; Corégonidés; comportement alimentaire.

1.0 INTRODUCTION

Renewed interest in natural gas pipeline development along the Mackenzie Valley has raised the prospect that fish species in the watershed may be impacted by changes to their habitat. The proposed pipeline would extend from near the Beaufort Sea coast to markets in the south (http://www.mackenziegasproject.com/). Fishes in the Mackenzie River depend upon the integrity of their aquatic habitats, so it is important to summarize knowledge that can be used to assess potential impacts of this development proposal and others, and to facilitate efforts to avoid and mitigate these impacts.

This report reviews knowledge of the diet of the round whitefish, *Prosopium cylindraceum* (Pennant, 1784). While it is common in Canada's northern lakes and rivers the round whitefish is one of the least studied coregonines, in part because of its slow growth and small average size which limit the species' commercial value (Koelz 1929; Mraz 1964; MacKay and Power 1968).

The round whitefish is widely distributed in Siberia and on the northern mainland of North America (Hale 1981). It occurs throughout the mainland of Alaska, Yukon and the Northwest Territories; in northern British Columbia; and throughout all but the northeastern corner of the Nunavut mainland (McPhail and Lindsey 1970; Scott and Crossman 1973; Stein *et al.* 1973; Hatfield *et al*. 1978; Lawrence *et al*. 1978; MacDonald and Fudge 1979; Lee *et al.* 1980; MacDonald and Stewart 1980; Stewart and Bernier 1983, 1984). It is common in the Mackenzie Valley and occurs in all ecozones of the Northwest Territories. Moving eastward there appears to be a gap in the species' distribution, with few reports of its occurrence between northwestern Manitoba and Lake Nipigon, ON. It is distributed downstream of Lake Nipigon in southern Ontario, Quebec, and New Brunswick, and several New England states, and is common in northern Quebec and Labrador.

Fluvial[1], **adfluvial**, **lacustrine** and **anadromous** life histories have been observed among round whitefish populations (Koelz 1929; Kra'sikova 1968; Normandeau 1969; Bryan and Kato 1975; Morin *et al.* 1982). In the southern part of their range, these fish are usually found in shallower areas of deep lakes, and in northern parts may also be found in rivers and streams (Scott and Crossman 1973). They enter brackish waters off the Mackenzie and Coppermine rivers (McPhail and Lindsey 1970; Scott and Crossman 1973), in Prudhoe Bay Alaska (Bendock 1977), and along the coasts of Hudson and James bays (Dymond 1933; McAllister 1964; Morin *et al*. 1980).

Very little is known of the species' diet within the Mackenzie watershed outside the summer season, about energy flow, or predation rates. This limits the ability to assess the effects of environmental changes on the species, particularly impacts related to

[1] Terms in bold type are defined in the Glossary.

pipeline development and climate change. This report presents a generic food web for round whitefish, based on data from the Mackenzie River watershed and elsewhere. It reviews knowledge of how the species' diet varies with geographical location, habitat type, season, life history stage, and competition. It also considers predation pressures and identifies knowledge gaps. Similar reports have been prepared for other fishes that inhabit the Mackenzie River watershed. Stewart *et al*. (2007) provide a recent review of habitat use by round whitefish.

2.0 FOOD WEB

Quantitative data from round whitefish populations in the Northwest Territories (NT), and Yukon (YT) were used to construct the generic food web (Figure 1) (Appendix 1, Appendix 2). Most of these studies were conducted during the summer, and small sample sizes often resulted in lumping together of juvenile and adult dietary data. These limitations make it difficult to compare dietary differences among populations, life stages, and seasons. They also limit what can be said about the energetic importance of each pathway.

The methods used to quantify round whitefish diet are not always directly comparable among studies. However, many of the studies used percent frequency of occurrence based only on stomachs that contained food. Where studies calculated percentages based on all stomachs examined, including those that were empty, the data were recalculated to base percentages only on stomachs with food (i.e., Kennedy 1949; Chang-Kue and Cameron 1980; Jessop *et al*. 1993). The basis for percentage calculations by Rawson (1951) and Armstrong *et al*. (1977) was not stated. Magnin and Clément (1979) also used Hynes' (1950) points method to assess stomach contents. They found that the percent frequency of occurrence tended to overestimate the dietary contribution of smaller taxa, particularly that of some Trichopterans, Dipterans, Ephemeropterans, and molluscs. Martin (2001) used the relative importance index developed by George and Hadley (1979).

Based on these data, a generalized food web has been constructed for the species (Figure 1). Aspects of this food web, including predators and dietary differences related to life history stage, habitat, and season are discussed below, as are the effects of inter- and intraspecific competition.

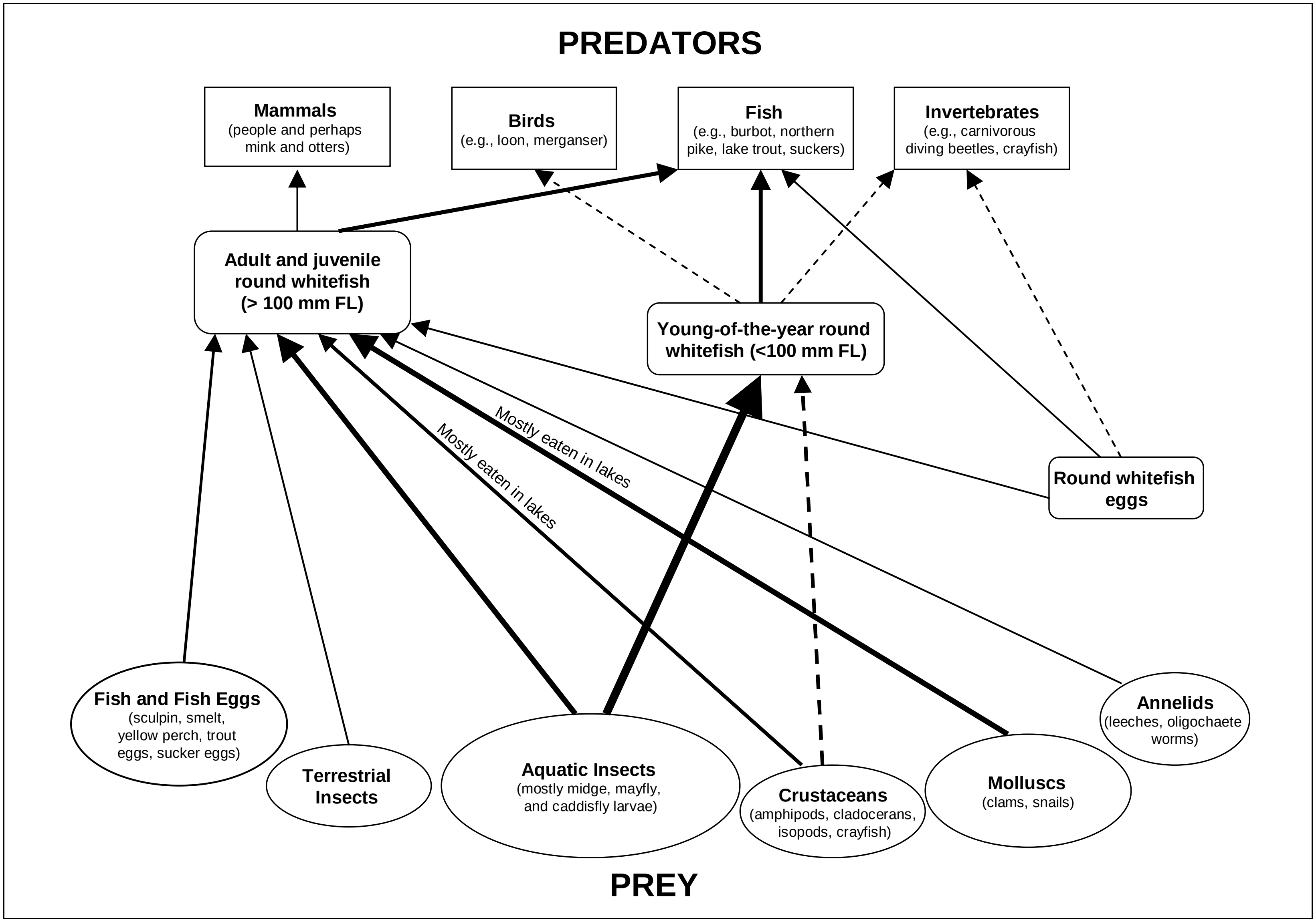

Figure 1. Generalized food web for round whitefish showing the direction of energy flow. Bold lines indicate major food pathways in comparison to thinner lines; solid lines indicate demonstrated pathways and dashed lines indicate putative pathways.

2.1 Predators

In Newfound Lake, New Hampshire, white suckers (*Catostomus commersoni*), yellow perch (*Perca flavescens*), burbot (*Lota lota*), brown bullhead (*Ameiurus nebulosus*), and post-spawning round whitefish eat round whitefish eggs (Normandeau 1969). The crayfish, *Oronectes limosus*, may also feed on eggs. Atlantic salmon (*Salmo salar*) and yellow perch may prey on newly hatched round whitefish fry on the spawning grounds. The presence of introduced smallmouth bass (*Micropterus dolomieu*) appeared to reduce round whitefish recruitment at lakes in the Adirondacks area of New York State (Steinhart *et al*. 2007; Weidel *et al.* 2007). Lower densities of round whitefish have also been observed in Ontario lakes where large burbot are present (Carl and McGuiness 2006). Adult round whitefish are eaten by northern pike (*Esox lucius*) (Rawson 1951) and lake trout (*Salvelinus namaycush*) (Koelz 1929; Harper 1948, 1961; Bendock 1980). The list of species that prey on round whitefish is likely much longer.

Some round whitefish populations in New York lakes have been able to cope with introduced species (Steinhart *et al*. 2007). However, the number of predatory warm water fish species present is an important determinant of whether lakes continue to support round whitefish. The appearance of smallmouth bass, rainbow smelt (*Osmerus mordax*), and yellow perch has often accompanied a decline or disappearance of both round and lake whitefish. The detrimental effect of predator introduction was demonstrated at Little Moose Lake, where the number of small round whitefish (<200 mm total length) increased exponentially after a program was begun to remove introduced smallmouth bass (Steinhart *et al*. 2007; Weidel *et al.* 2007). This increase suggests that round whitefish experienced substantial predation losses when large smallmouth bass were present in the littoral zone (Weidel *et al.* 2007).

Round whitefish are seldom targeted by commercial and subsistence fisheries because they are typically less abundant and smaller than lake whitefish (*Coregonus clupeaformis*) (Miller 1947; Scott and Crossman 1973; McCart and Den Beste 1979). They are caught incidentally in gill nets during fisheries targeting other species, but do not follow a lead readily so they are seldom taken in pound or trap nets (Koelz 1929). Because of their smaller average size, preference for living in deeper water, and habit of feeding on small, bottom-dwelling invertebrate species, round whitefish are caught less frequently by angling than are lake whitefish (Department of Environmental Conservation 1999). While the flesh is tasty (McCart *et al*. 1972), cysts of the parasite *Triaenophorus crassus* that are common in round whitefish from some lakes can also make them less attractive to harvesters (Miller 1947; Scott and Crossman 1973; Stewart and Bernier 1999). The species is much less vulnerable to overharvesting than other species such as Arctic grayling (*Thymallus arcticus*), Dolly Varden (*Salvelinus malma*) and walleye (*Sander vitreus*) that are predictably available in large numbers at rivers or small streams.

2.2 Prey

As the terminal placement and small size of its mouth suggests, the round whitefish preys mostly on small benthic organisms (O'Brien *et al*. 1979). Lack of a linear relationship between prey size and predator size, suggests that the round whitefish is an opportunistic predator (Guinn 1982). During the open water period, juveniles and adults feed on a variety of aquatic insect larvae, pupae and nymphs; on benthic molluscs; small crustaceans; fish eggs; and fish. Young-of-the-year eat mostly aquatic insect larvae and pupae. However, adults in some lakes prey heavily on *Daphnia* spp. (Steinhardt *et al*. 2007), so the young fish likely eat crustacean zooplankton as well.

2.2.1 Young-of-the-year

In Siberia young feed in the upper reaches of streams and along the shores of lakes (Kra'sikova 1968). Unlike other coregonines they feed actively before the yolk sac is completely absorbed (Shestakov 1991). Passive dispersal of yolk sac larvae by currents may be an important means of reducing competition for food among the larvae. Yolk sac larvae (12.1-15.4 mm) in the Anadyr River (Chukotka) are passively dispersed downstream in late May through mid June, and larger larvae (mean body length 29.7-39.6 mm) continue to be dispersed downstream through July (Shestakov 1991, 1992). During their descent the larvae attempt to move into the shallows to begin feeding and further movement occurs along the shore. Juveniles in the Susitna River, Alaska, also move downstream to the lower river for rearing during their first year (Sundet and Wenger 1984).

Few data were located on the diet of young-of-the-year round whitefish in stream environments and none from lakes, where fry have proven difficult to locate. Fry and fingerlings examined during the open water season from two Mackenzie River tributaries, Oscar Creek and the Trail River (Jessop *et al*. 1974), and from the Chena River in Alaska (Lee 1985) often contained midge larvae (Chironomidae) and sometimes mayfly larvae (Ephemeroptera), caddisfly larvae (Trichoptera), blackfly pupae (Simuliidae), and/or water mites (Arachnida). In laboratory experiments, young-of-the-year fed mostly on the bottom (Lee 1985). Feeding at the surface was not observed but feeding occurred in the drift.

2.2.2 Juveniles and Adults

During the open water period, round whitefish in rivers (Appendix 1) and lakes (Appendix 2) eat similar taxa, but those in the lakes tend to eat more benthic molluscs. Fish in Lake Michigan ate more large crustaceans, including both isopods and crayfish (Decapoda), than fish elsewhere (Armstrong *et al*. 1977). These dietary differences likely reflect the local availability of these taxa.

Aquatic insect larvae, particularly midges, mayflies and caddisflies, occur frequently and often in quantity in the stomach contents of round whitefish summering in rivers (McCart *et al*. 1972; Jessop *et al*. 1973, 1974; Stein *et al*. 1973; Craig and Wells 1975; Magnin and Clément 1979; Chang-Kue and Cameron 1980; Chang-Kue *et al*. 1987; Zyus'ko *et al*. 1993). Few of the fish sampled contained taxa with terrestrial origins. Amphipods, molluscs, and fish were found more often in the diet of fish from more southerly populations, such as those at Rivière La Martre, Northwest Territories, and La Grande Rivière, Quebec, than in those to the north. This likely reflects the fact that larger samples were examined from these populations, although it could reflect differences in the local availability of these taxa, competition with other species, or dietary preferences.

Round whitefish adults, like Arctic grayling adults, appear to select for streams with higher than average benthic invertebrates standing crop and diversity (Den Beste and McCart 1984). Fish from lakes or larger rivers may undertake summer feeding excursions into tributary streams (McCart *et al*. 1972). In Russia, the July and August feeding rate can be considerably higher in streams than in lakes (Kra'sikova 1968).

Aquatic insects, molluscs, and crustaceans occur frequently, and often in quantity, in the stomach contents of round whitefish summering in lakes (Kennedy 1949; Rawson 1951; McPhail and Lindsey 1970; Armstrong *et al*. 1977; Guinn 1982; Merrick *et al*. 1992; Jessop *et al*. 1993; Martin 2001; Steinhart *et al*. 2007). Midge larvae, caddisfly larvae and pupae, and sometimes mayfly larvae were the aquatic insects encountered most frequently. Clams (e.g., Sphaeridae) and snails (e.g., *Lymnaea* sp. and *Planorbis* sp.) were also common in the stomachs of northern lake populations. As in the rivers, more taxa were found in the stomachs of fish from the southern lakes -- likely for the same reasons.

Foraging round whitefish may have distinct, albeit variable, search images (Kennedy 1949; Steinhart *et al*. 2007). On the same date in Buck Pond, New York, three fish were captured that ate exclusively *Daphnia* spp., three predominately caddisflies, two mostly damselflies, one almost entirely dragonflies, and one that ate a little of all prey types (Steinhart *et al*. 2007). Likewise, most fish sampled from Great Bear Lake contained only one type of prey (Kennedy 1949).

Adult round whitefish in Toolik Lake, a small kettle lake in Alaska, were strongly demersal with molluscs being the dominant food group found in their stomachs (O'Brien *et al*. 1979; Merrick *et al*. 1992). Fish captured near the lake outlet contained more clams, chironomids and trichopteran larvae, and fewer of the gastropod *Lymnaea,* than fish captured over shoals. Percentages of fish consuming the gastropod *Valvata* were similar in both areas.

Round whitefish summering in Great Slave Lake had eaten mostly aquatic insects and molluscs (Rawson 1951). Caddisfly larvae and pupae constituted 43% on average of the volume of the stomach contents, gastropods 35%, and aquatic diptera 21% -- mostly midge and horse or deer fly larvae (Tabanidae). The general dominance of these biota in the stomachs reflects the fish's habit of feeding in shallow inshore areas. Algae, especially colonies of *Nostoc,* were common in the stomach contents. Whether they were consumed accidentally is unknown. In Great Bear Lake, aquatic insect larvae, mostly caddisfly larvae but also chironomid, mayfly and cranefly larvae, comprised most of the stomach contents (Kennedy 1949; Falk and Dahlke 1974). Terrestrial insects were next in importance; and plankton, molluscs, and fish eggs were also eaten.

Koelz (1929) examined the stomachs of 50 round whitefish collected from Lake Huron in October and November. The main items found were gastropods, larval and pupal caddisflies, and larval mayflies. Adult insects, larval midges, isopods (*Asellus* sp.), crayfish (*Cambarus* sp.), Bryozoa, plant remains and sand were also ingested.

Fish eggs may be a seasonally important food for round whitefish. One of the species' common names in New Hampshire is “shad waiter”, which refers to their habit of waiting for shad (*Alosa sapidissima*) to spawn so that they can eat the eggs (Harper 1961). They have also been observed hovering above spawning longnose (red) suckers (*Catostomus catostomus*), presumably waiting to feast on the newly laid eggs. Koelz (1929) baited hooks with trout eggs and found that they immediately attracted round whitefish. He also sampled round whitefish on trout spawning grounds in Lake Huron, and found that the majority with food in their stomachs had eaten trout eggs.

Round whitefish also eat small fish, or parts of them. Slimy sculpins (*Cottus cognatus*) have been found in round whitefish from Simmons Lake, British Columbia (Guinn 1982). Round whitefish using the estuary of Grand rivière de la Baleine, on the Quebec coast of Hudson Bay, also ate sculpins (F. Cottidae) (St. Arsenault *et al*. 1982). Rainbow smelt are eaten by round whitefish in the La Grand River of Quebec (Magnin and Clément 1979) and in Lake Michigan (Armstrong *et al*. 1977), and yellow perch are eaten in Lake Opeongo, Ontario (Sandercock 1964). Round whitefish near the tailrace of the Ludington Pumped Storage Power Plant on Lake Michigan will eat parts of alewife (*Alosa pseudoharengus*) that have been chopped up by the turbines (Peterson *et al*. 1980).

Round whitefish will bioaccumulate polychlorinated biphenyls (PCBs) and dichlorodiphenyl trichloroethane (DDT) residues as they grow (Miller and Jude 1984). Likewise, fish in environments that have received mercury-laden industrial discharges will accumulate mercury in their flesh, but at a lower level than predatory species such as northern pike and lake trout (Moore and Sutherland 1980; Lafontaine 1994). Round whitefish from lakes in a watershed containing uranium mining and milling operations at

Elliot Lake, Ontario, concentrated radionuclides (^{226}Ra, ^{210}Pb, ^{210}Po) in their bones and flesh (Clulow *et al*. 1998a+b). The activity levels of the radioactive materials in the fish tissues was low but regular monitoring of ^{210}Pb levels in the fish flesh was recommended from watersheds containing uranium operations.

2.2.3 Seasonal

Changes in round whitefish diet during the open water period have been examined at lakes in southern Ontario both in the presence and absence of lake whitefish (Sandercock 1964), and at Lake Michigan (Armstrong *et al*. 1977). No studies were found of the diet of round whitefish under winter ice cover.

In Lake Opeongo, Ontario, caddis fly larvae were the most important food item for round whitefish in May, with dragonfly naiads somewhat less so (Sandercock 1964). During this time **sympatric** lake whitefish fed almost entirely on mayfly nymphs. As the summer progressed the caddis fly larvae contributed less to the round whitefish diet which shifted towards chironomid larvae and pupae and, to a lesser extent, mayfly nymphs *(Hexagenia*). Bottom-dwelling zooplankters were only consumed in any quantity in June and July, and even then their relative importance did not exceed that of the insect larvae. Molluscs and other items such as yellow perch and water mites were minor dietary items for the round whitefish.

In Happy Isle and Redrock lakes, Ontario, which lacked lake whitefish, the cladoceran, *Daphnia longispina,* was a major contributor to the round whitefish diet (Sandercock 1964). Bottom fauna constituted a smaller proportion of the diet than in Opeongo Lake, despite having a relative abundance that was similar or greater. Crustacean zooplankton were also the most important dietary item of round whitefish in several lakes in the Northwest Territories (Rawson 1951; Martin 2001) and New York (Steinhart *et al*. 2007) where lake whitefish were absent. Round whitefish taken on 10 July in Artillery Lake, upstream of Great Slave Lake, had eaten large quantities of Cladocera (Rawson 1951). Whether the planktivory of these fish might be an artefact of examining fish collected earlier in the season is unknown.

In Lake Michigan, snails (Gastropoda: primarily *Physa*) and midge larvae (Chironomidae: primarily *Chironomus* sp., *Cryptochironomus* sp., and *Procladius* sp.) were most frequently eaten by round whitefish in the spring, summer and fall, and constituted the greatest percentages of the diet on a total volume and numerical basis (Armstrong *et al*. 1977). Several items were seasonally important including: leeches (Hirudinea) which constituted a greater proportion of the spring diet, crayfish (Decapoda) in the summer, and fish eggs in the summer and fall.

A “summer squeeze” may occur in some lakes, such Lower Cascade Lake in New York State, where warm surface waters and low oxygen at the bottom limit round whitefish movements into the surface and bottom waters (G. Steinhart, Lake Superior State University, Sault Ste. Marie, MI, pers. comm. 2007). This phenomenon appears to limit the growth rate of affected round whitefish populations.

Adults appear to stop feeding during the spawning period (Normandeau 1969; Craig and Wells 1975). In Newfound Lake, New Hampshire, the stomachs of round whitefish caught prior to the onset of spawning were usually full, with *Daphnia pulex* being the most abundant food item (Normandeau 1969). During spawning few of the over 200 fish examined had food in their stomachs.

2.3 Competitors

Competition may occur between lake and round whitefish (Sandercock 1964). Round whitefish typically occupy a shallower depth range when they occur sympatrically with lake whitefish than when lake whitefish are absent. Likewise, lake whitefish are typically found in deeper water when round whitefish are present (Carl and McGuiness 2006). The former may compete more effectively for crustacean zooplankton (Sandercock 1964) and the latter for benthic invertebrates (Carl and McGuiness 2006). Lake whitefish population size and density declines in the presence of round whitefish (Carl and McGuiness 2006).

Changes in the morphological characteristics of round whitefish that share Simmons Lake (British Columbia, 59°11´N, 129°47´W) with mountain whitefish (*Prosopium williamsoni*) suggest that the round whitefish are affected by competitive interactions with these fish (Guinn 1982). There is dietary overlap between these species. Absence of a linear relationship between prey size and predator size suggests that the round whitefish are opportunistic feeders, whereas the presence of a linear relationship for mountain whitefish indicates greater dietary specialization. Mountain whitefish can colonize lakes containing round whitefish, perhaps because of their more riverine habits, but never become abundant if both lake and round whitefish are already present.

There is dietary overlap between young-of-the-year round whitefish, Arctic grayling and chinook salmon (*Oncorhynchus tshawytscha*), with the round whitefish having the least diverse diet (Schallock 1966; Lee 1985). All three species frequent the same habitats and tend to seek deeper, faster water as they grow. However, differences in emergence times and sizes tend to segregate the species, with the round whitefish occupying depths intermediate between the other two species except immediately after emergence. In the laboratory, among fish of the same length, the more aggressive grayling will displace round whitefish from their preferred habitat (Lee 1985). In Alaskan streams the habitat size used by adult round whitefish (335 m^2) was about twice that used by adult grayling, and reflects the whitefish's preference for large pools (Den Beste and McCart 1984).

Intraspecific competition may also limit round whitefish growth. Following the start of a smallmouth bass removal program, catch rates of small round whitefish increased exponentially in Little Moose Lake, New York (Steinhart *et al*. 2007). At the same time the condition of round whitefish in the lake declined. This decline, coupled with the observation that high density populations in other lakes also tended to be skinnier, suggests that round whitefish growth may be limited by intraspecific competition.

3.0 SUMMARY

Round whitefish prey opportunistically on small benthic organisms in shallow inshore waters of lakes, rivers, and estuaries. Individuals may have distinct, albeit variable, search images. During the open water period, juveniles and adults eat a variety of aquatic insect larvae, pupae and nymphs, benthic molluscs, small crustaceans, fish eggs, and fish. Young-of-the-year eat aquatic insect larvae and pupae, and may also eat small crustaceans. Fish in lakes may eat more molluscs and small crustaceans than those in rivers. They also may move into streams to feed. Little is know of seasonal changes in the species' diet or about its winter diet.

Piscivorous fishes are likely the key predators on the round whitefish, which is seldom targeted for harvest. In northern waters, the eggs are likely eaten by suckers, burbot, and members of their own species, and the fish are eaten by lake trout, burbot and northern pike. Intra- and interspecific competition for food may limit round whitefish growth. Small crustaceans may contribute more to the species' diet in the absence of lake whitefish, and in early spring. The introduction of warm water predators such as smallmouth bass, yellow perch, and rainbow smelt can cause populations to decline.

The round whitefish's ability to exploit a range of benthic prey, as well as zooplankton and terrestrial drift, is likely one of the key factors that enables it to inhabit **oligotrophi**c lakes across the Northwest Territories and Nunavut. As a generalist feeder, it is likely a key link in food webs that lack the biological productivity to sustain more specialized feeders.

4.0 ACKNOWLEDGEMENTS

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6.0 GLOSSARY

Adfluvial fish populations move between lake and river or stream environments.

Anadromous fish populations undertake move downstream into marine waters to feed, and return upstream into fresh water to spawn and/or overwinter.

Fluvial fish populations remain in rivers and streams throughout their lives.

Lacustrine fish populations live and reproduce in lakes.

Oligotrophic lakes have low biological productivity due to low nutrient levels, and typically have very clear water.

Piscivorous species eat fish.

7.0 APPENDICES

Data are presented in Appendix 1 on the prey of round whitefish in rivers, and in Appendix 2 on their prey in lakes.

Key to Appendices 1 and 2:

Where the life stage or terrestrial origin of taxa consumed was noted in the original report, it is denoted as follows: **A** = Adult, **L** = Larvae, **P** = Pupae, **N** = Nymph, **T** = Terrestrial origin. With the exception of insects, most unlabelled taxa were adults.
+ = present in small amounts.
* = fish are considered to be age 0 until December 31 of the year they are hatched.

References:

1 = Stein *et al*. 1973—includes data from Hatfield *et al*. 1972a+b
2 = Jessop *et al*. 1993—recalculated percentages based only on stomachs with food.
3 = Chang-Kue and Cameron 1980—recalculated percentages based only on stomachs with food.
4 = Magnin and Clément 1979
5 = Merrick *et al*. 1992—additional taxa from O'Brien *et al*. (1979) are indicated with a "+".
6 = Martin 2001
7 = Lee 1985
8 = Armstrong *et al*. 1977—percentages may be based on all stomachs or just those with food.
9 = Chang-Kue *et al*. 1987—recalculated percentages based only on stomachs with food.
10 = Rawson 1951—percentages may be based on all stomachs or just those with food.
11 = Kennedy 1949—recalculated percentages based only on stomachs with food.
12 = Craig and Wells 1975

Notes:

a = % frequency of occurrence,
b = relative importance index (George and Hadley 1979—cited by Martin 2001)

Appendix 1. Stomach contents of round whitefish, expressed as percent frequency of occurrence, from rivers in Alaska (AK), the Northwest Territories (NT), and Quebec (QC). Percentages are based only on stomachs that contained food. See above for explanatory key.

	Chena River, AK	**Chandalar River, AK**	**Mackenzie River watershed, NT**		**Great Bear River, NT**	**Rivière la Martre, NT**	**La Grande Rivière, QC**
Season	Jun-Sep	summer			Jun-Sep	May-Sep	Aug-Oct
Coordinates	64°47'44"N, 147°54'43"W				64°54'N, 125°35'W	63°16'01"N, 116°32'05"W	53°50'N, 79°00"W
Elevation (m asl)	~400						
Life history type (F= fluvial; A = Adfluvail)	F	F, A?	F, A?	F, A?	F	F	F
Life stage (J = juvenile; A = Adult)	J	J, A	J	J, A	J, A	J, A	
Age range*	yoy				~3-12*	5-10	
Length range (mm fork length)	34-61	~83-440	30-137	163-432	~280-480	~351-525	~200-300
# of stomachs examined (# empty)	9	60 (30)	13 (0)	20 (16)	17 (10)	89 (36)	89
Plant Material (including phytoplankton)				25		19.1	3
Invertebrates					42.9		
Ph Annelida							
SubCl. Hirudinea (leeches)						9.0	
SubCl. Oligochaeta							
Ph. Arthropoda							
Cl. Arachinda (arachnids, water mites)	11						
Cl. Insecta (insects)			46.1	25		1.1(T)	
O. Coleoptera (beetles)		7 (L)				2.3 (L), 3.4 (A)	1
O. Diptera (gnats, mosquitoes, flies)	11 (L)		7.7	25	28.6 (L)	6.7 (L)	62 (L)
F. Ceratopogonidae (biting midges)			15.4				
F. Chironomidae (midges)	100 (L)	63 (L) 7 (P)	23.1		42.9 (L)	14.6 (L), 6.7 (A)	
F. Simuliidae (blackflies)	22 (L)						
F. Tabanidae (deer and horse flies)							
F. Tipulidae (crane flies)		17 (L)					
O. Ephemeroptera (mayflies)			7.7			5.6 (L)	13
F. Baetidae			15.4				
F. Heptageniidae	33 (L)						

O. Hemiptera (true bugs)							3
F. Corixidae (water boatmen)						19.1	
O. Neuroptera (lacewings)							1
O. Odonata (dragonflies)						9.0 (N)	
O. Plecoptera (stoneflies)		17 (N)		25		2.3 (N)	2
F. Nemouridae (spring stoneflies)							
F. Perlidae (common stoneflies)							
F. Perlodidae (perlodid stoneflies)			7.7	25			
O. Trichoptera (caddisflies)		33 (L)	7.7	25		29.2 (L)	83 (L)
SubPh. Crustacea							
Cl. Isopoda							
Cl. Malacostraca							
O. Amphipoda (e.g., *Gammarus lacutris, Hyalella azteca, Pontoporeia affinis)*)						20.0	4
SubO. Cladocera (water fleas)							
O. Decapoda (crayfish)							
Cl. Ostracoda (seed shrimp)						1.1	
Ph. Mollusca							
Cl. Bivalvia (clams)						3.4	11
Cl. Gastropoda (snails)			7.7			9.0	20
Lymnaea							
Fishes					28.6	40.5	3
F. Osmeridae (smelts)							
Osmerus mordax (smelt)							
F. Cottidae (sculpins)							4
Fish eggs							
Debris/detritus		13			28.6		22
Miscellaneous (e.g., parasitic nematodes; surface drift)	11						
Reference:	7	12	1	1	3	9	4
Notes:	a	a	a	a	a	a	a

Appendix 2. Stomach contents of round whitefish from lakes in Alaska (AK), the Northwest Territories (NT), and Michigan (MI). Contents are expressed as percent frequency of occurrence based on stomachs that contained food, except at Lac du Gras. See above for explanatory key.

	Toolik Lake, AK	**Indin Lake, NT**	**Lac du Gras area lakes, NT**	**Great Bear Lake, NT**	**Great Slave Lake, NT**	**Lake Michigan, MI**		
Season	Jun-Jul?	May-Sep	Jun-Aug	summer	Jul-Aug	Spring	Summer	Fall
Coordinates	68°37'57"N, 149°36'17"W	64°15'N, 115°05'W	~64°30'N, 110°30'W	63°50'N, 120°45'W	63°30'N, 114°00'W		43°30'N, 87°30'W	
Elevation (m asl)	720	273	396	156	156		176 m	
Life history type (L=Lacustrine)	L	L	L	L	L		L	
Life stage (J = juvenile; A = Adult)	A	J, A	J, A	A	J, A		A, J	
Age range*		~2-8*		~6-13	~0-13		~0-7 (most 3-4)	
Length range (mm fork length)	428±4	~207-498	142-454	~250-500			~123-538 (most 340-460)	
# of stomachs examined (# empty)	71	34 (3)	40 (9)	72 (27)	178 (30)	147 (7)	113 (10)	380 (86)
Plant Material (including *Nostoc* and phytoplankton)					+			
Invertebrates								
Ph Annelida								
SubCl. Hirudinea (leeches)						17.1	5.8	0.7
SubCl. Oligochaeta						5.7	6.8	0.7
Ph. Arthropoda								
Cl. Arachinda (arachnids, water mites)		3.2			+	0.7	2.9	2.0
Cl. Insecta (insects)	1.4 (T)		1.2 (T)	55.6 (L) 37.8 (T)				
O. Coleoptera (beetles)		3.2 (A)	2.5		+	0.7	1.0	
O. Diptera (gnats, mosquitoes, flies)		48.4 (L) 32.3 (P)						
F. Ceratopogonidae (biting midges)								
F. Chironomidae (midges)	45.1		20.2		21 (L)	92.1 (L)	57.3 (L)	61.6 (L)
F. Simuliidae (blackflies)								
F. Tabanidae (deer + horse flies)					+			
F. Tipulidae (crane flies)				+				
O. Ephemeroptera (mayflies)						13.6	1.9	2.0
F. Baetidae								
F. Heptageniidae								
O. Hemiptera (true bugs)							1.0	
F. Corixidae (water boatmen)								

O. Neuroptera (lacewings)								
O. Odonata (dragonflies)								
O. Plecoptera (stoneflies)		3.2 (L)	0.5			2.1		
F. Perlodidae (perlodid stoneflies)								
O. Trichoptera (caddisflies)	67.6 (L)	83.9 (L)	16.4		82 (L, P)	12.9	14.6	8.2
SubPh. Crustacea			47.9	11.1				
Cl. Isopoda						9.3	3.9	3.4
Cl. Malacostraca								
O. Amphipoda (e.g., *Gammarus lacutris, Hyalella azteca, Pontoporeia affinis)*)		3.2			+	14.3	2.9	1.4
SubO. Cladocera (water fleas)	+						3.9	0.3
O. Decapoda (crayfish)						4.3	13.6	12.9
Cl. Ostracoda (seed shrimp)								
Ph. Mollusca	83.1		6.6	4.4				
Cl. Bivalvia (clams)	31.0 Sphaeridae	9.7			+	9.3	23.3	4.8
Cl. Gastropoda (snails)		54.8				30.0 mostly *Physa*	66.0 mostly *Physa*	61.2 mostly *Physa*
Lymnaea	36.6							
Planorbis	43.7				51			
Fishes								
F. Osmeridae (smelts)								
Osmerus mordax (smelt)						0.7		
F. Cottidae (sculpins)								
Fish eggs						5.7	15.5	13.6
Debris (includes unidentified insect parts, baby lemmings, refuse, caribou hair, feathers, sticks, plastic ribbon, rocks)		3.2						
Miscellaneous (e.g., parasitic nematodes; surface drift)		6.5				7.9	4.9	2.0
Reference:	5	2	6	11	10	8	8	8
Notes:	a	a	b	a	a	a	a	a